charles river analytics

Charles River Analytics Inc.
625 Mount Auburn St.
Cambridge, MA 02138

www.cra.com

p: 617.491.3474
f: 617.868.0780

15 MAR 2009

Reference: Government Contract No. N00014-09-C-0050, “Enhancing Simulation-based Training Adversary Tactics via Evolution (ESTATE)”
Charles River Analytics Contract No. C08098

Subject: Contractor’s Status Report: Quarterly Status Report #1
Reporting Dates: 12/15/2008 – 03/15/2009

Dear Dr. Hawkins,

The following is the Contractor’s Quarterly Status Report for the subject contract for the indicated period. During this reporting period work has concentrated on Task 1: Identify Training Goals, Task 4: Develop Trainee Model Processing, and Task 6: Perform Simulation-based Training System Integration

1. Summary of Progress

1.1 Kickoff Briefing

A kickoff briefing was held on 2 FEB 2009 at the Office of Naval Research in Arlington, VA. Present were Brad Rosenberg (Principal Investigator) from Charles River Analytics and Prof. Jordan Pollack (Technical Advisor) from Brandeis University. From the Office of Naval Research, Dr. Harold Hawkins (Program Officer) and Ms. Annetta Burger were present. Brad Rosenberg led the discussion, which explored the program motivation, approach, and goals for the base year period.

During the discussion, it was revealed that the ESTATE effort falls within a larger initiative for “Training Adaptability” within the Office of Naval Research. The adaptive training research initiative can be decomposed into two fields: 1) creating adaptive training systems, and 2) creating systems that train adaptability. ESTATE primarily addresses the first field, with the added benefit of indirectly addressing the second. ESTATE supplies adversaries in a simulated environment that adapt to the strengths and weaknesses of an individual trainee, creating a tailored training experience to facilitate accelerated skills development and sustainment. This promotes active learning, reduces costs, and adds realism to training systems. Furthermore, by providing an adaptive adversary, ESTATE compels a trainee to adapt, training measure-countermeasure problem-solving skills.

The initial research under previous efforts for ESTATE was primarily focused in the convoy operations domain. While that domain was determined to be high-priority given

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **15 MAR 2009**	2. REPORT TYPE	3. DATES COVERED **15-12-2008 to 15-03-2009**

4. TITLE AND SUBTITLE **Enhancing Simulation-Based Training Adversary Tactics via Evolution (ESTATE)**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Charles River Analytics Inc,625 Mount Auburn St,Cambridge,MA,02138**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

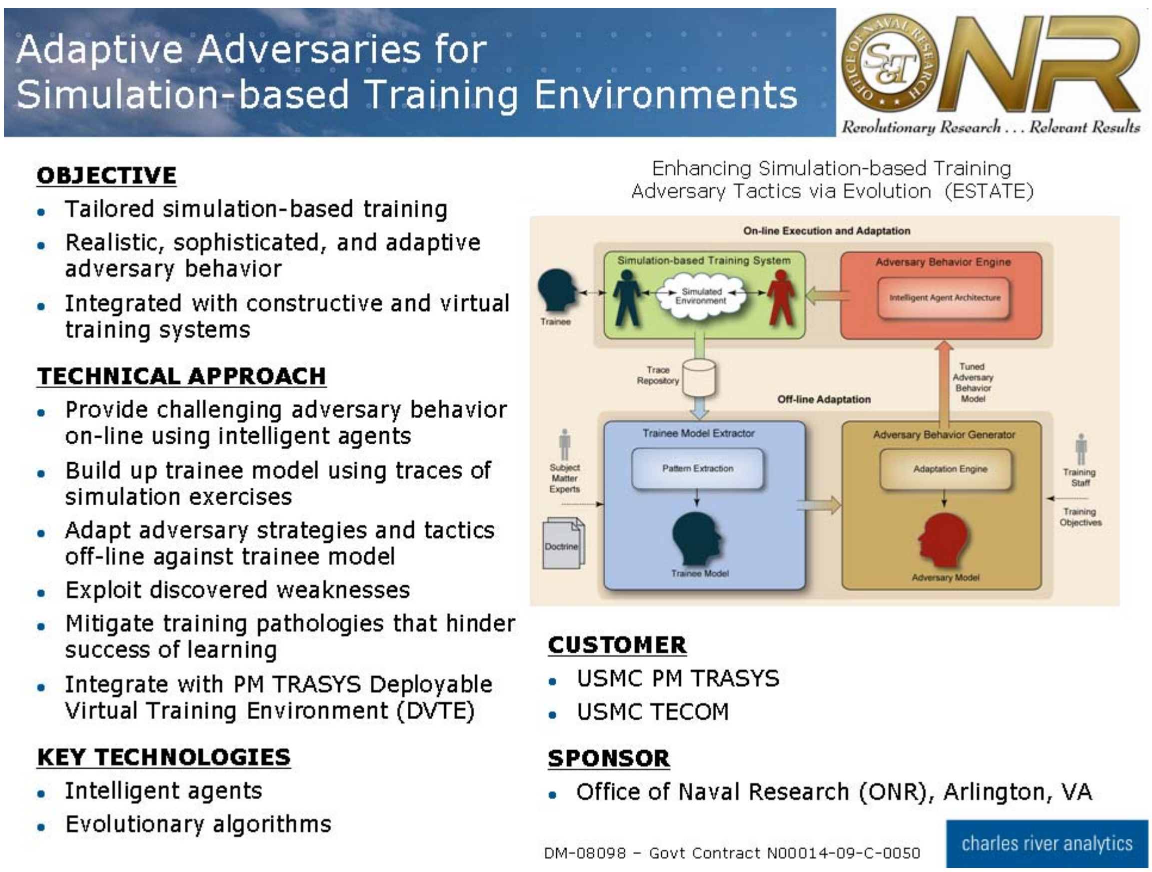
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

the current operational climate, it was not a good match for training opportunities that an adaptive simulation-based training system could provide. During the kickoff briefing, it was decided that the target domain should be reopened, with a focus towards squad-level behaviors. We are currently exploring training literature to determine current gaps in training at this level and its match to a simulation-based training approach.

Discussion also led to programmatics regarding when decisions need to made regarding continuing the research under the Year 2 option (Option 1). As that decision needs to be made by OCT/NOV, it would best serve for a demonstration or briefing be prepared for late summer, early fall such as the SEP 2009 timeframe. We have adapted our program plan accordingly to have a demonstration ready by this time.

Furthermore, at the time of the kickoff briefing, the ESTATE program had only partial funding allocated for the base year portion of the effort. As of 18 FEB 2009, the base year period has now been fully funded and Option 1 has been exercised.

It was also requested during the kickoff briefing that a Quad Chart be generated that is simpler, conveys the overall program goals, and could be used as a promotional introduction to the ESTATE effort for a military officer. A copy of that Quad Chart is presented below.



1.2 Requirements Analysis

During the indicated period, we performed a literature review in the area of learning science to help ground ESTATE system design and development in solid concepts. Additionally, we engaged with PM TRASYS to help determine training requirements for the Marine Corps.

1.2.1 Literature Review

Several learning theories help provide a framework for training systems. These learning theories fall under three categories: behaviorism, cognitivism, and constructivism. Behaviorism is concerned with how the environment shapes behavior and focuses learning on the acquisition of new behavior through conditioning (classical condition or operant condition). Cognitivism attempts to look beyond overt behavior and focuses instead on memory and prior knowledge as the two critical aspects of learning. Alternatively, constructivism views learning as a process on the active construction of knowledge based on current and past knowledge. It is this last category, constructivism, that we are concerned with. Aspects of constructivism are found in experiential learning and situated cognition. The premise of these concepts is "learning by doing", which has strong parallels to the Marine Corps training approach of "train as you fight." As a result, simulation-based training enables Marines to "train as you fight," and is the approach taken within ESTATE.

During the indicated period, we discovered that the ESTATE framework is functionally similar to the field of *intelligent tutoring systems*. Intelligent tutoring systems derived from computer-aided instruction in education and rose in popularity during the 1980s-1990s given increases in computational power. Intelligent tutoring systems are comprised of three major components: an *expert model*, a *student model*, and an *instructor model*. The expert model represents subject matter expertise and problem solving ability and is used to help compare a learner with an expert. The student model attempts to evaluate the learner's performance to determine knowledge, skills, and abilities. Finally, the instructor model encodes instructional methods that are appropriate to the target domain (represented in the expert model) and the learner. Within ESTATE, the expert model is encoded as the mission essential task lists and key performance indicators as specified by training doctrine. The student model is the trainee model processing component of ESTATE. The instructional model is ESTATE's adversary adaptation component. We intend to leverage this knowledge as we move forward with the ESTATE research.

In "Foundations of Intelligent Tutoring Systems"[1], VanLehn describes student modeling as inferring a model of the student's current understanding of the subject material. This process is referred to as *diagnosis*. The goal of diagnosis is to uncover hidden cognitive states of the student from observable behavior. These hidden cognitive states are called *latent traits* in the literature, and refer to the knowledge, skills, and

---

[1] VanLehn, K. (1988). Student Modeling. In Polson, M.C., Richardson, J.J. (Ed.), *Foundations of Intelligent Tutoring Systems* (pp. 55-78), Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

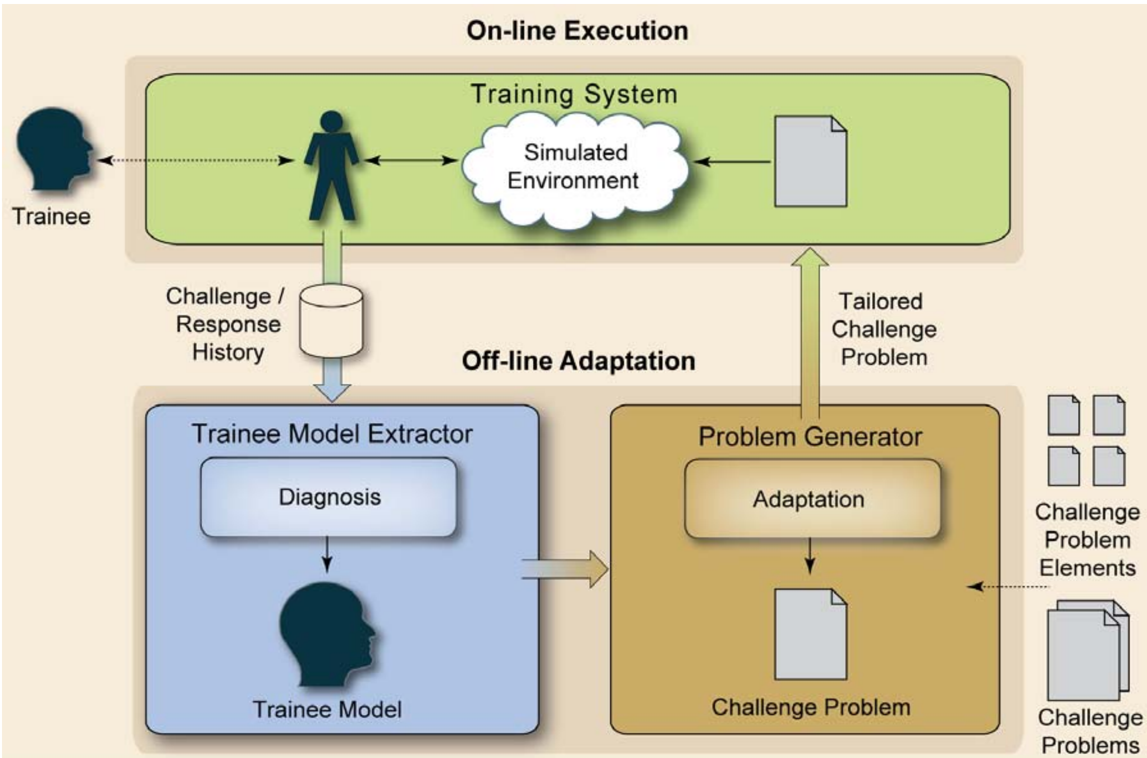
abilities of our trainees in ESTATE. The student model can then be used for many different things within an intelligent tutoring system, one of which is problem generation. This is the current usage within the ESTATE system, generating an appropriate challenge that promotes learning.

There are several dimensions to diagnosis, including bandwidth, target knowledge type, and student-expert difference. Bandwidth is the amount of information that can be gleaned from the system for diagnosis. It includes approximate mental states, intermediate states, and final states. Approximate mental states provide transparency into the cognitive processes of the student and provide the highest amount of bandwidth to glean information from. Intermediate states, however, are closed to what is going inside the head of the trainee and only observes behavior (e.g., mid-game board positions in chess). Final states only enable the capture of information at the end of the interaction (e.g., win/loss, final score), and provide the lowest amount of bandwidth. While more information usually beneficial, it adds complexity to capture and utilize that data within the intelligent tutoring system. For the purposes of ESTATE, we will assume that we will begin with the final states (i.e., the performance of the trainee given a challenge) with an eye towards intermediate states in the future.

Target knowledge types distinguish how to apply knowledge in the student model to the problem. VanLehn describes two types of knowledge, procedural knowledge and declarative knowledge. Procedural knowledge makes decisions based on local knowledge by applying procedures based on the situation and applying it to a task while declarative knowledge searches the whole knowledge base. Under ESTATE, we will assume that the knowledge we are trying to convey is procedural, in the context of performing a specific function or task, which is learned experientially.

Finally, the last dimension of interest is student-expert difference. This feature attempts to define how a model of the student's knowledge differs from an expert. The simplest form is of overlay, where the student is an expert with some missing knowledge. However, this can be made more complex by imagining that a student additionally has some misconceptions, or "bugs", that hinder learning. In this format, a bug library can be created that defines the incorrect knowledge the student has. If these bugs can be decomposed into their component parts, then a bug part library can be created, where bugs can be assembled dynamically that are specific to an individual student. For the purposes of ESTATE, we will make the assumption of overlay, that a student is an expert that is simply missing certain knowledge, skills, or abilities.

Using intelligent tutoring systems research as a guiding principle in the ESTATE framework, we then attempted to formulate an initial training system within the scope of the base year period. While a real-time military simulation is the eventual goal, a more feasible approach is needed to design, develop, and evaluate an adaptive training system. Since we have made the initial assumptions of using final states, teaching procedural knowledge, and using an overlay form of student modeling, we have targeted challenge / response games as a first approach for ESTATE. Within a challenge / response framework, a challenge problem is presented to the trainee, who then attempts to respond to the challenge in the appropriate manner, doing so either correctly or incorrectly (a graded scale of performance is also possible). Based on this response, a new challenge can be generated and presented next that promotes learning. We believe this provides a general framework within scope. It is also possible to envision that a challenge / response game can be conceived of as a generalization of a tactical simulation, where the challenge is a tactical situation with simulated entities and the response of the trainee is realized as specific actions in that situation. The figure below represents the ESTATE architecture in this new conceptual framework.



Under the upcoming period, we plan on adapting some of the challenge / response games from the BeeWeb program (http://www.beeweb.org) from Brandeis University to this framework. Specifically, we are looking into MoneyBee, a money exchange game that teaches algebra, logic, and estimation. We are hoping this simple game will allows us to help define problem difficulty dimensions, trainee skill dimensions, and a dynamic difficulty assessment and problem generation system. We are also looking into how item response theory[2] may have a role in this process.

1.2.2 Discussion with PM TRASYS

During the indicated period, initial discussions were held with Ms. Nancy Harmon of PM TRASYS starting 3 MAR 2009 to help identify training requirements and gaps (both from a domain and technical perspective) and to gain information about constructive

[2] Baker, F.B., (2001), *Basics of Item Response Theory*, ERIC Clearinghouse on Assessment and Evaluation, College Park, MD.

training systems at PM TRASYS. Ms. Harmon formerly led PM TRASYS in constructive simulations, but is now focused on immersive simulation technologies.

Regarding training requirements and gaps, Ms. Harmon indicated that she is in possession of Marine Corps training material that includes task lists and performance measurement criteria that is releasable to help guide ESTATE system development. We are currently in the processing of obtaining that material. Additionally, Ms. Harmon indicated she has connection to military subject matter experts (i.e. Captain, Gunnery Sergeant) currently aiding PM TRASYS in this area that could help in the requirements analysis process. These same SMEs could then participate in formative and summative evaluations of the ESTATE software prototype. The goals of the ESTATE program would then be to enter into a Memorandum of Agreement (MOA) or Technology Transfer Agreement (TTA) with PM TRASYS.

In addition to training requirements and gaps, the discussion with Ms. Harmon helped assess simulation as a training system technology. It was noted that while the Deployable Virtual Training Environment (DVTE) is being utilized in PM TRASYS, that the Combined Arms Network (CAN) component is receiving less use than the tactical decision-making simulations (TDS) within DVTE. Specifically, VBS2 is receiving considerable focus. VBS2 is being looked at as an interim technology for creating immersive simulated environments with an eye towards the DARPA REALWORLD program to supplant it in the future. As a result, we will focus our initial assessment on VBS2 as a target simulation-based training system. Ms. Harmon is currently putting us in touch with the DVTE Project Officer so we can gain access to DVTE.

2. Scheduled Items

- Obtain training manuals and other guiding documents from PM TRASYS to help determine target training domains
- Obtain DVTE from the program office for in-house evaluation and development
    - Primary focus on VBS2 to assess integration points for intelligent behavior of simulated entities.
- Design of a formal framework for challenge / response games that is extensible for initial system development and experimentation
- Application of the MoneyBee game to the challenge / response game framework for experimentation

Sincerely,

Brad Rosenberg
Principal Investigator